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EFFECTS OF ASPECT ON WEATHERING: ANOMALOUS BEHAVIOUR OF SANDSTONE GRAVESTONES IN SOUTHEAST ENGLAND

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ABSTRACT

Rocks in the humid temperate zone tend to weather more severely on faces exposed to the prevailing winds than on their more sheltered leeward faces. In southeast England, however, gravestones composed of a non-local, quartz-rich sandstone exhibit a reverse weathering pattern. The east-facing, lee sides exhibit a much greater depth and areal extent of weathering than the west sides which face the westerly wind and rain. Possible reasons for the asymmetric pattern of weathering are discussed. Copyright © 2000 John Wiley & Sons, Ltd.

KEY WORDS: aspect; asymmetrical weathering; gravestones; sandstone; weathering processes

INTRODUCTION

It has often been suggested that rock outcrops, stone buildings and gravestones in the humid temperate zone weather more rapidly on the sides facing the prevailing wind and rain than on their sheltered or lee sides. For example, Geikie (1887) noted that marble gravestones in Scottish churchyards are most deeply etched and furrowed on their exposed western sides;Worth (1930) reported that the granite tors on Dartmoor, England, are most rounded and roughened on their windward-facing southwest sides, and Matthias (1967) found that inscriptions on arkosic tombstones in Connecticut are most weathered on their west faces, which are the most exposed to wind and rain. Clifton-Taylor (1981, p. 39), discussing a sandstone town house in England, commented that stone facades on the lee sides of buildings ‘have always been less vulnerable to decay’ than those facing the prevailing wind, and Mottershead (1994, 1997) has shown that sandstone and greenschist stonework on the coast of southwest England is most weathered where it is directly exposed to the prevailing winds.

The blackening of stone buildings through the accumulation of soot and other pollutants is often strongly influenced by compass direction. The effect is most marked on limestone buildings, where surfaces exposed to wind and rain undergo solutional lowering which often prevents soot from accumulating, with the result that only the sheltered sides of the buildings become blackened (Schaffer, 1932; Camuffo *et al.*, 1983). In addition, black gypsum crusts, which develop when gaseous SO_2 and sulphur-rich combustion particles react with the limestone, tend to be most widely developed on the sheltered sides of buildings. Sandstone buildings can also acquire gypsum crusts, particularly on their lee sides, where rainwash is minimal (Smith *et al.*, 1994). However, in contrast with limestone buildings, it is usually facades facing the prevailing wind that suffer the greatest black soiling. In central England, for example, the exposed south and west sides of sandstone churches are the most blackened (Halsey *et al.*, 1995a, 1995b, 1996).

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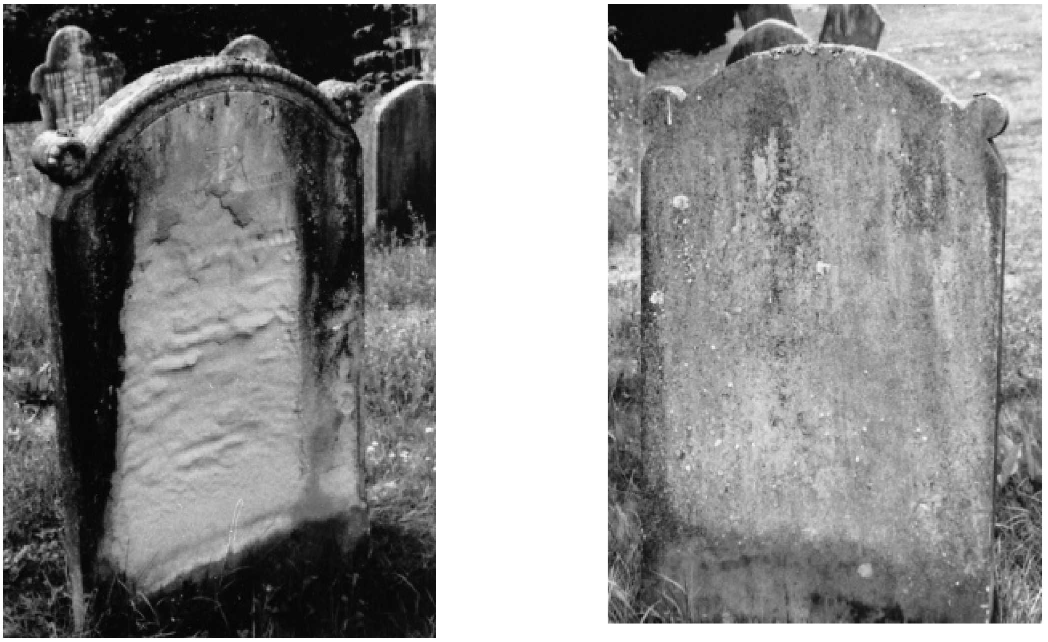

Figure 1. Victorian gravestone in Rusper churchyard (West Sussex) showing typical east–west weathering asymmetry. Left: the highly weathered east face has lost all trace of the original inscription. Right: the much less weathered west face. Note how the base, top and side edges of the stone are less weathered than the central portion

HEADSTONE ORIENTATION AND WEATHERING

This paper reports a situation where the control exerted by aspect on weathering rates is the reverse of the accepted norm, where at least partial shelter from the prevailing wind and rain results in considerably greater damage than full exposure. It describes the weathering behaviour of sandstone headstones (Figure 1) in churchyards in the Weald of southeast England, an essentially rural environment. Only headstones constructed of a distinctive type of non-local sandstone are discussed; headstones of local sandstone exhibit a different breakdown pattern (Robinson and Williams, 1999).

The majority of the graves in churchyards in the Weald, as in other parts of Britain, have headstones erected with their two main sides facing east and west. The consistent orientation of the headstones renders them especially suitable for studying the influence on weathering of east–west contrasts in aspect.

PROPERTIES AND PROVENANCE OF THE SANDSTONE

Unweathered, the sandstone under study is light grey with a hint of olive yellow (Munsell 5Y 6·5/2). It is fine grained, even textured, and shows few signs of bedding or layering. The porosity is around 14·5 per cent, and about 9 per cent of particles by weight are silt- or clay-sized.

Highly quartzose, the sandstone contains only occasional grains of feldspar (<5 per cent), mostly orthoclase or microcline. Muscovite occurs as scattered flakes. The quartz grains are sub-angular to sub-rounded, and generally well coated with particles of secondary silica (Figure 2). Particles and grains of iron oxide or hydroxide are distributed throughout the sandstone, and small hematite-rich, shaley nodules are sometimes present. Energy dispersive spectroscopy for relatively unweathered samples of the sandstone shows, in addition to silicon, significant components of aluminium, potassium and iron.

When the sandstone weathers, it develops a well marked crust that is a drab olive grey at the surface but foxy red beneath (Munsell 2·5YR 5·5/7). Subsequent loss of surface through granular disintegration or breaching of the crust often exposes the red underlayer. It is this tendency to ‘blush’ that makes the sandstone highly distinctive.

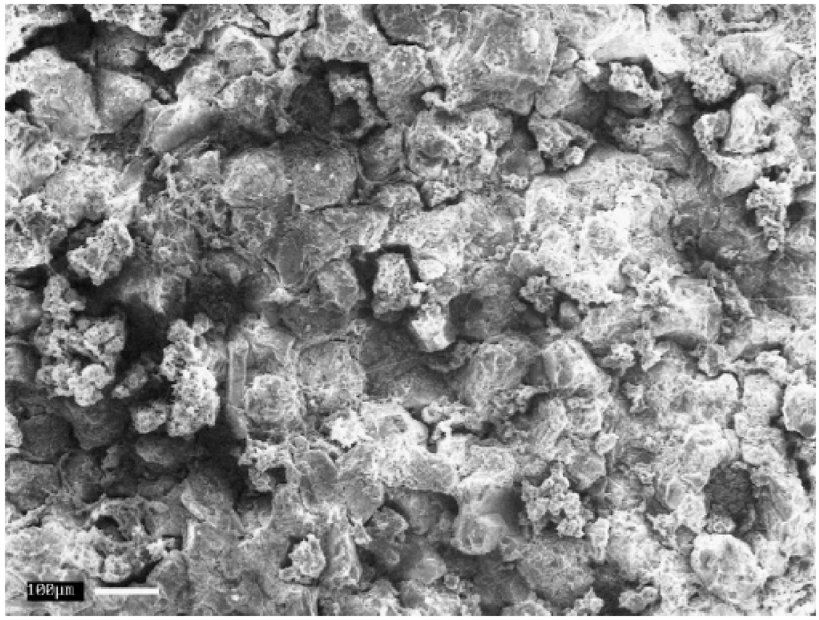

Figure 2. Scanning electron microscope image of a fragment of a surface spall from a gravestone erected in 1906 in Cuckfield churchyard (West Sussex). The quartz grains are coated in secondary silica which acts as a cement. One oblong grain of albite is visible left of centre

Gravestones made from this sandstone can be found outside the southeast in many parts of eastern, central and northern England, as well as in Scotland. The earliest examples date from around 1815, but the peak period of usage was 1870 to 1910, when the sandstone appears to have outsold every other type of monumental sandstone. Sales declined rapidly around the time of the First World War, and few, if any, gravestones made from this sandstone were erected after the late 1920s.

The identity of this once fashionable sandstone remains uncertain, despite many consultations with stonemasons and geologists. Its texture and mineralogical content is insufficiently distinctive to locate an exact source, but closely match some Coal Measure sandstones of South Yorkshire (Graham Lott, pers. comm.). It seems very likely that the Sheffield area, and perhaps also the Rothwell area southeast of Leeds, was the source of many of the gravestones, but some may come from other Coal Measure outcrops.

Coal Measure sandstones around Sheffield were widely quarried in the 19th and early 20th centuries (Eden *et al.*, 1957), partly for building stone and grindstones (Lewis and Rees, 1926) but also for gravestones (Hunt, 1860). Production ceased as Sheffield grew and the quarries were built over. Exposures of the likely source sandstones are now very limited, which makes comparison with the gravestone material difficult. Sandstone from the same geological formation is still quarried at Shepley, north of Sheffield, but it is quite different in character from the sandstones that are thought to have been used for the gravestones.

Though often soot encrusted, the Coal Measure sandstones used to build many Victorian and Edwardian houses and walls at Handsworth and other places on the eastern edge of Sheffield display blushing tendencies. The effect is most marked on window surrounds, gate posts and quoins where, as in gravestones, the bedding lies vertical. Walling stones laid with the bedding horizontal only rarely blush. We have also noted blushing on Coal Measure sandstone walls at Rothwell and Robin Hood near Leeds.

Although blusher-type gravestones are present in most churchyards in the Sheffield and Leeds areas, they appear to be much less frequent than in many other parts of the country. This is puzzling if the stone was actually quarried locally. Perhaps the heavily polluted atmosphere that existed until recently, especially in the Sheffield area, inhibited blushing. Many of the gravestones in the churchyards have very thick black coatings, which may mask blushing or even prevent its development.

Figure 3. Surface spalling on an 1892 gravestone in Cuckfield churchyard

WEATHERING FEATURES

In the Weald, the imported sandstone gravestones develop a hardened crust or coating, from 1 to 4 mm thick. Even the youngest gravestones, erected in the period 1900–1927, have pronounced crusts. Scanning electron microscopy reveals that the quartz grains forming the crusts have become coated and cemented by secondary silica deposits. Both iron and silica are evidently drawn to the surface and deposited to form the crust. The grey–green coloration of the crust surface seems to be due to accumulation of algal remains and deposition of wind-borne particulates such as soot. The red underlayer owes its colour to the presence of relatively large amounts of iron oxides. Immediately beneath the crust the sandstone is often particularly weak, apparently because iron and silica have migrated in solution into the hardened crust.

Despite developing a crust, the sandstone remains vulnerable to rapid breakdown under weathering attack (Figure 3). The crust easily detaches from the underlying rock and blister-like domes often develop as the crust bows out; these then rupture releasing spalls 1–4 mm thick, in a similar manner to the blisters that develop on limestone walls (Viles, 1993). In some cases the blisters are only a few tens of millimetres in diameter and are sharply defined, but sometimes a large section of the face lifts up as a gently curving sheet. Once the crust has been ruptured, the softer rock beneath is often rapidly consumed by multiple flaking and granular disintegration. The flaking does not appear to pick out original laminations in the rock and its causes are uncertain, though cycles of heating and cooling and/or wetting and drying may be responsible (Smith *et al.*, 1994). Individual flakes are often only one or two sand grains thick and very fragile. Although often associated with multiple flaking, granular disintegration also occurs in its absence.

Owing to continuing wastage, the original surface of the headstones can become severely hollowed out. However, no cases have yet been found where the headstones have become perforated by weathering attack, as has occurred in Derbyshire (Derek Mottershead, pers. comm.), Staffordshire and West Yorkshire.

Inscriptions on the headstones, which seem to be protected by the formation of the crust in the early stages of weathering, often start to become hollowed out as the crust finally breaks down. The end result in many cases is a type of honeycomb weathering, with massed hollows retaining the spacing but little of the form of the original letters. Occasionally, honeycomb weathering develops on the non-inscribed sides of the gravestones, as at Ticehurst churchyard on stones dating from the 1890s.

Once the crust has been breached, weathering and erosion usually remain active and a crust does not redevelop. However, in a significant minority of cases, initial breaches recrust and active erosion ceases. This phenomenon also occurs on Sussex sandstone outcrops and churches (Robinson and Williams, 1996). Why some breaches heal in this way whilst others continue to erode remains a mystery, but changes in the local environment such as the degree of shelter or shade may be responsible.

MEASUREMENT PROCEDURES

The effects of aspect on weathering rates and amounts were assessed by comparing the maximum depth and area of rock removed by weathering on the east and west faces of the five or ten most weathered headstones in a sample of ten churchyards or parts of churchyards. Gravestones located under trees or next to church walls were ignored, as were gravestones leaning appreciably to the east or west. An engineer's gauge reading to 0·1 mm was used to measure the maximum depth of hollowing out of each gravestone face. A steel rule or perspex bar resting on flat areas that appear to form part of the original surface was used to bridge the hollows and provide a datum plane for the measurements. Obvious flaws in the stone, carved inscriptions and omamentation were avoided.

Although more detailed measurements could have been obtained, for example by laser scanning (Swantesson, 1994), the method employed has the advantage of allowing a large sample of gravestones to be assessed relatively quickly and with reasonable precision. The measurements obtained are likely to underestimate the true maximum depths of weathering since the flat areas on which the rule was rested, which are assumed to form part of the original surface, may in fact have been reduced somewhat by granular disintegration.

In addition to measuring the maximum depth of weathering, the areal extent of the hollows was estimated visually in order to determine whether the eastern or western face of each gravestone has suffered the greater volume of surface loss.

SURVEY RESULTS

Table I summarizes the data for the ten churchyards. Of the 135 gravestones surveyed, 86 per cent have lost a larger volume of material on their eastern than western sides. The maximum depth of weathering is on average three times greater on the eastern than on the western sides (10·4 mm as against 3·5 mm). Visits were also made to 28 other churchyards and a further 303 east–west facing gravestones inspected (Table II). Although detailed depth measurements were not made, 83 per cent of the stones show maximum weathering on their eastern sides.

The data in Table I suggest that the inscription sides of gravestones have a similar weathering potential as the backs. Churchyards that have gravestones with inscriptions facing east show much the same degree of weathering asymmetry as churchyards with gravestone inscriptions facing in the reverse direction, and there are no obvious differences in asymmetry where the gravestone inscriptions in one area of a churchyard face east and in another area face west. One might have expected that carving the inscriptions would 'bruise' the surrounding stone making it less durable, and that the inscriptions would allow weathering processes easy access to the interior of the gravestones, but this is refuted by the data in Table I.

There are considerable differences in the maximum depth of weathering between churchyards. In part this is likely to be because the churchyards differ in wind exposure, soil moisture conditions and other environmental factors. However, the method of sampling is most probably a contributory factor since it selects the most deeply weathered stones. Churchyards with numerous gravestones are likely to yield higher values of maximal weathering than churchyards with few gravestones. Random sampling would have eliminated this bias, but it could not be used because of the difficulties of accurately measuring slight amounts of weathering and of identifying the sandstone in the absence of blushing. By concentrating on the most badly weathered stones, the present study has minimized measurement and identification errors.

In British churchyards it is usual to find that the older gravestones are more weathered than the newer stones and their inscriptions are less legible. However, the data collected in the present study suggest that the

Table I. Weathering depths on the most heavily weathered gravestones composed of non-local sandstone in ten Wealden graveyards

Churchyard	Inscription on		Range of dates	Maximum weathering on			Mean of maximum depth	
	West	East		West	East	Equal	West	East
Cuckfield (1)	10	0	1861–1885	0	8	2	3·3	8·9
Cuckfield (2)	0	10	1881–1910	0	10	0	2·4	6·4
Frant (1)	5	0	1861–1888	2	3	0	16·2	15·1
Frant (2)	0	5	1831–1909	0	5	0	2·8	5·2
Goudhurst	10	0	1826–1899	1	9	0	3·2	9·0
Hartfield	9	1	1847–1898	5	5	0	7·1	4·7
Haywards Heath (1)	5	0	1871–1891	1	4	0	0·6	16·2
Haywards Heath (2)	0	5	1894–1898	0	5	0	2·4	5·5
Rusper	0	10	1866–1897	3	7	0	4·7	11·1
Steyning (1)	10	0	1861–1903	1	8	1	2·4	4·5
Steyning (2)	0	10	1860–1915	1	8	1	2·3	7·3
Wadhurst (1)	10	0	1871–1894	0	10	0	2·2	22·5
Wadhurst (2)	0	10	1880s–1890s	0	10	0	3·3	35·1
Wivelsfield	0	10	1869–1904	2	8	0	3·9	3·0
Worth (1)	10	0	1833–1922	0	10	0	0·1	2·3
Worth (2)	0	5	1887–1941	0	5	0	1·4	9·0
Total/mean	69	66		16	115	4	3·5	10·4

maximum depth of weathering on both the east and west sides of the gravestones is wholly unrelated or only very weakly related to the age of the stones indicated by the inscription date ($r = -0{\cdot}10$ and $-0{\cdot}08$ respectively with $n = 112$). Aspect is a much more powerful determinant of weathering rates and amounts than the period of exposure to the weather (58–173 years). The explanation presumably lies in the episodic nature of the spalling, which is the dominant weathering process affecting the sandstone under study. No significant spalling is likely to have occurred for many years after the stones were erected. If it had, stonemasons would have quickly abandoned using the sandstone. Nevertheless, ample time has now elapsed for spalling to affect many of the gravestones in each churchyard. The thickness of the spalls is apparently controlled by factors other than the length of time of exposure.

There is almost no correlation between maximum depths of weathering on the east and west sides of each gravestone ($r = -0{\cdot}07$, $n = 135$). This suggests that the gravestones under study have fairly similar strength properties. If some gravestones were particularly strong and others markedly less durable, east and west side weathering depths could be expected to show a significant degree of correlation. The absence of a convincing correlation may also indicate that the weathering processes operate more or less independently on the two sides of the stones.

Table II. Weathering asymmetry of gravestones composed of non-local sandstone in Wealden churchyards

Location	East > west	West > east	East = west
East Hoathly, Framfield, Buxted, Hadlow Down, Old Heathfield and Mayfield	20	4	1
North Chailey, Ditchling and Patcham	31	3	5
Midhurst, Easeboume, Stedham, Trotton and Harting	13	3	0
Slindon, Boxgrove, Tangmere and Aldingbourne	14	5	0
Billingshurst, Wisborough Green, Kirdford, Alfold and Dunsfold	51	3	0
Westerham, Limpsfield, Oxted, Tandridge and Godstone	124	17	9
Total	253	35	15
Percentage	83	12	5

Table III. Weathering asymmetry of gravestones composed of non-local sandstone in two Wealden churchyards where the orientations are anomalous

Churchyard	Inscription on		Range of dates	Maximum weathering on		Mean of maximum depth	
Horley	WNW	ENE	1867–1904	WSW	ENE	WSW	ENE
	2	8		0	10	1·9	24·5
Eridge	SW	NE	1861–1918	SW	NE	SW	NE
	0	10		1	9	1·4	11·5

There is a highly significant degree of correlation between the heights of maximum weathering on the east and west sides of the gravestones ($r = 0{\cdot}47$, $n = 55$). This may relate to soil moisture conditions and similar amounts of capillary rise on the two sides of the gravestones. However, the zone of weathering is about 41 per cent more extensive on the east sides than the west sides. Thus, not only are the east sides more deeply weathered than the west sides, but the area undergoing visible weathering is also greater.

The churchyards listed in Tables I and Table II all have gravestones that face east or west to within about 10°, except Hartfield where the stones face ESE and WNW (about 110° and 290°) and are thus angled more nearly edge-on than normal to the prevailing southwest wind. It is interesting that Hartfield is the only churchyard with significant numbers of headstones where the weathering is on average greater on the west sides than on the east.

Data from two churchyards where the gravestones face more directly into the prevailing wind than normal are presented in Table III. At Horley the gravestones face ENE and WSW, while at Eridge the alignment is almost exactly NE and SW. In both churchyards the pattern of damage is normal: at Horley all ten gravestones show maximum damage on the east, at Eridge the proportion is nine out of ten.

Although very much in a minority, gravestones that are most weathered on their western faces should not be dismissed as chance aberrations. They often occur in clusters, especially on the western sides of churchyards, and the reverse weathering asymmetry that they exhibit can be quite extreme, with the east faces showing almost no signs of weathering and the west faces badly weathered-out.

It is very noticeable in all the churchyards that the least damaged parts of the faces of headstones are the bases, and to a lesser extent the tops (Figure 1). The edges, including the top edge, also exhibit little damage. Generally, the faces of headstones are most deeply hollowed out at or just above their midpoint. However, in a significant minority, damage is greatest near the top of the face, especially if the upper edge of the stone is cut into a sharply pointed arch or bow.

DISCUSSION

The predominance of east-side weathering shown by the gravestones conflicts with the commonly held view that weathering is most rapid on rock surfaces that face the prevailing wind and rain. It is also at variance with the weathering pattern shown by gravestones of locally quarried Hastings Beds sandstone in the Weald (Robinson and Williams, 1999). These tend to be more deeply weathered on their western than eastern sides, although the depths are generally quite small, and the stones are on average much better preserved than the gravestones made of the non-local sandstone, despite being of greater age.

The dramatic weathering asymmetry exhibited by the non-local gravestones mirrors the asymmetry seen on Wealden church towers constructed of Hastings Beds sandstone (Robinson and Williams, 1996). The east sides of the towers are noticeably more weathered than the west sides, irrespective of the age of the church. The northern sides of towers built in the 19th and 20th centuries are distinctly more weathered than the southern sides, but on medieval towers the difference is quite minor. Although no gravestones have been found facing north and south, the fact that the gravestones at Eridge are much more weathered on their northeast than southwest faces suggests that, as well as east predominating over west, north predominates

over south as a control on weathering loss. The alignment of the Eridge stones reduces the potential effect of the strong east–west contrast in weathering rates while giving opportunity for a north–south contrast to have effect. If south predominated over north, this would tend to cancel out the predominance of east over west.

The predominantly east side weathering exhibited by the gravestones appears to be due more to a difference in weathering intensities than to types of processes. The east sides regularly undergo spalling, multi-layer flaking and granular disintegration whereas the west sides tend to be virtually pristine or show only surface spalling, but in the few cases where the weathering asymmetry is reversed, multi-layer flaking and granular disintegration are also active on the west sides. Measurements of spalls suggest that the thickness of the surface crust is very similar on the two sides. There is no convincing evidence that the crust is weaker and less indurated on east sides, thus predisposing the vulnerable interior to breakdown. The assumption must be that the environmental conditions to which the east face is exposed are more severe, causing more frequent rupturing and breaching of the crust. Once the crust is breached, weathering losses on the east face tend to continue or even increase, but on the west face breaching and crusting appear more episodic, with breached areas more readily becoming restabilized through further crusting.

The weathering asymmetry, although perhaps best developed in the open, exists also under long-established trees, even evergreens such as yew and holly that cast a permanent shade. The only qualification is that there must normally be quite a high canopy; gravestones that are enveloped in ground-level foliage rarely show weathering asymmetry. This suggests that wind and rain, which can penetrate under tree canopies, probably play a much greater part in the formation of the weathering asymmetry than temperature changes induced by diumal heating and cooling. When the air is still and rain falls vertically, the gravestone tops become soaked long before the sides, and during brief showers the sides may escape wetting altogether. When the prevailing wind is blowing from the west, the westem faces of the stones soon become wetted but the sheltered east faces tend to remain dry except along their top and side edges. It cannot be mere coincidence that the more frequently rain-soaked parts of the gravestones tend to resist weathering whereas the more sheltered parts often undergo rapid breakdown.

Rain soaking is probably not the only way that moisture differences control the weathering of the gravestones. The tendency for them to be well preserved at soil level suggests that rising damp plays a part in preserving the base of the gravestones. At higher levels, there may be a wick effect (Goudie, 1986), which may help to explain why many stones tend to suffer their greatest degree of weathering around their central point. However, it is hard to see how this can explain the weathering asymmetry since capillary rise could be expected to be much the same on both sides of the gravestones, despite different temperature regimes and degree of exposure to rain and wind. The thinness of the gravestones (60–120 mm) ought to assist moisture transfer between the west and east faces, helping to promote equal amounts of dampness at any given height above soil level.

The actual processes of weathering are less easy to ascertain than the environmental controls. The role of frost weathering remains uncertain. The gravestones almost certainly suffer more frequent and more intense freeze–thaw cycles than rock outcrops or building stones because of their thinness and exposed position. Moisture may become trapped behind the surface crust, leading in frosty weather to the formation of miniature ice lenses and detachment of the crust. Salt weathering is another possibility. A few gravestones have obvious salt efflorescences at their base, and small amounts of salt are sometimes present on the inner sides of spalls of hardened crust or on the rock surfaces beneath, especially surfaces that are undergoing multiple flaking following loss of the outer crust. Headstones that lean eastwards are often particularly deeply hollowed out on their eastern sides by weathering. The hollows, which resemble shallow tafoni, provide a sheltered micro-environment which might favour salt accumulation.

The salt on the gravestones is mainly gypsum, although small amounts of halite are sometimes also present. The gypsum results from the evaporation of salts drawn up through the sandstone from the soil and not from any reaction between calcium minerals in the rock and air-borne sulphur dioxide, as is the case with limestones in polluted environments.

Despite the presence of the salts on the gravestones, there is no clear evidence that they are causing damage. Scraping the salt efflorescences off the surface of the rock does not result in any significant removal of sand grains. The amounts of salt on spalls and flaking surfaces are so small that it is difficult to believe that

they are causing the weathering. Laboratory experiments suggest that even saturated solutions of gypsum cause only minor damage to sandstones and other rocks (Goudie, 1985; Williams and Robinson, 1998).

The fact that the sandstone is quartz-rich does not make it immune from chemical weathering. Swelling and rupture of the crust may be greatly assisted by chemical weathering of some of the minor constituents, in particular decomposition of the mica flakes and feldspar grains, hydration of any clay minerals that are present, and oxidation of iron minerals towards the base of the crust, as suggested by the development of the foxy red blush.

The more stable surfaces of the gravestones have light coverings of lichens and algae, but the more rapidly weathering surfaces are quite bare. Beneath some lichens the surface sand grains are loose, and, when the lichens die and become detached, the grains are readily removed by wind and rain. In a few cases, lichens appear to cause blistering and the lifting of the surface crust from the rock beneath. Nevertheless, the resulting amounts of surface lowering are quite small. There is no reason to suppose that bioerosion is creating the weathering asymmetry; indeed in a small way it may be acting to reverse the asymmetry by attacking only the more stable surfaces.

Case hardening of exposed surfaces is a common feature of many sandstones (Robinson and Williams, 1987, 1994) and is often accompanied by sub-surface weakening. The case hardening appears to result from a transfer of silica and iron from the interior to the outer layers of the rock, possibly aided by biogenic agencies. When used as headstones, thin slabs of sandstone undergo case hardening on all sides, and both the hardening and the related internal weakening are able to develop to an extreme degree.

The quarries that we believe were the source of the headstones also produced paving slabs, lintels and building stones (Hunt, 1860). When used for these other purposes, the quarried stone appears to have suffered less weathering than when used as headstones. Particular beds within the quarries may have been reserved for the production of headstones because of their favourable jointing or other characteristics, and these beds may have been of less durable stone. Nevertheless, it is probable also that erecting thin slabs upright in the ground facilitates the weathering of sandstone. Headstones are likely to be especially vulnerable to weathering because of their high surface area to volume ratio, the vertical orientation of their bedding planes, and their susceptibility to rising ground moisture and salts. It has long been acknowledged that building stones laid with their bedding planes vertical tend to weather more rapidly than stones laid with their bedding planes horizontal (Schaffer, 1932 Ashurst and Dimes, 1977). An even greater difference in weathering response could be expected between thin slabs of stone stood upright in the form of headstones and laid flat as paving stones.

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